# Soil Parameters Analysis of Al-Najaf City in Iraq: Case Study

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## Abstract

*The soil properties are an important parameter for architectural and structural design of structures. Al-Najaf city in Iraq is a famous tourist destination, so in the last one decade a number of multistory buildings, bridges, highways, schools, hospitals, etc. have been constructed. This study investigates the properties of the soil to give a base data, which can be used for the future construction design. The physical and chemical soil properties were investigated and analyzed. The results show that the most of the soil is classified as a sandy soil with little fines having a cohesion varying from 0 to 13.2 kPa and angle of internal friction varying from 26.3 to 41.2 degrees; while liquid and plastic limits (LL and PL) vary from 21 to 29% and from 11 to 15% respectively. The low values of LL and PL for the soil of western locations increase towards the eastern locations. The values of maximum dry density and optimum moisture content vary from 17.5 to 19 kN/m³ and 8.6 to 13.2% respectively. The studies also show that the organic content and sulphate content have a low varies between 1 and 2.9% and 2.2 and 2.7% respectively while the gypsum content varies from 13.6 to 28.3%. The assemblages of gypsum soil concentrated in the west side of the city.*

*Keywords: Soil parameters, soil characteristics, Atterberg limits, physical and chemical properties*

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## INTRODUCTION

The basic objectives of research are to predict the properties of the stratigraphy and nature of subsurface materials, then analyze it and their expected behavior under the structure loadings and to permit savings in design and construction costs. The investigation is expected to reveal adverse subsurface conditions that could lead to construction difficulties, excessive maintenance, or possible failure of the structure. The scope of investigations depends on the nature and complexity of subsurface materials and the size, requirements for, and cost of the structure.

Al-Saoudi *et al.* investigated the rate of water infiltration through the base and side walls of a pit with dimensions 3 m by 3 m and 0.5 m in depth excavated and filled with water in the location of the artificial lake in a planning of a new tourist city called Sayf Thulfiqar city in Al-Najaf city [1]. The process of filling was repeated several times with full observation and continuous field measurements. The results show that the cumulative infiltration in cm for the four stages demonstrated an increasing trend with increasing cumulative time. This is in close agreement with the ideal shape in terms of the pattern of function; also the ideal relationship between the cumulative infiltration and time for tourist city soil is presented by an equation in the study with a good agreement between predicted and measured values.

Aziz and Abdulsattar presented a theoretical model by using PLAXIS 2D Professional v.8.2 to study the improvement of bearing capacity of gypseous soil under circular footing [2]. The soil samples used in the study were brought from one location at Al-Nda'a quarter west of Al-Najaf city. The soil samples were obtained from a depth of (3–4) m below the natural ground surface, the physical and chemical properties of the soils are investigated to use in PLAXIS. Soil parameters c and $\phi$ were founded as 2 kPa and 32° respectively. The gypsum content was founded as 32 percent.

Masum *et al.* studied the development of strength and compressibility correlations of cohesive soils of some regions at Khulna city in Bangladesh [3]. The strength parameters and compressibility parameters to liquid limit, plasticity index and initial void ratio of cohesive soil of the study area have been described graphically; and correlation among strength parameters, compressibility parameters and index properties of soil has been made. Also the values of strength and compressibility parameters of cohesive soil have been furnished with lowest and highest range. The value of unconfined compressive strength, undrained shear strength, N-value, compression index, recompression index and coefficient of consolidation of cohesive soil of the study area were found in ranges between 20 and 128 kPa, 10 and 64 kPa, 2 to 13, 0.243 to 0.705, 0.00678 to 0.082 and 0.000714 and 0.0201 cm$^2$/sec respectively.

Khan and Khan determined the properties of the soil of Abha city which is located in semi-arid cold climate region of the Kingdom of Saudi Arabia to provide a base data which can be used for the construction design [4]. The soil properties were analyzed in terms of pH, conductivity, moisture content, bulk density, dry density, silt content etc. The study concluded that the soil properties are better for structural development than greenification. But still the quality of soil is better than the most area of the Kingdom.

## MATERIALS AND TESTING
### Study Area
Najaf province, one of the eighteen provinces of Iraq, is far from the capital Baghdad, 161 km. The city is located on the edge of the plateau of western Iraq, southwest of the capital Baghdad. The rising city is 70 m above sea level. The west border of the city is a low water region called Bahr Al-Najaf and the east is an agricultural area penetrating by one of the Euphrates River branch called Shatt Al-Kufa. The samples of soil used in this study were taken from five sites in the city. Table 1 shows the sites which are selected to take the samples from in the city and represent the localities.
### Methodology
From the five selected locations presented in previous section an identified samples. Each sample is taken by 2 m hand auger tool and the

properties of samples were investigated. For each samples, the classification according to Unified Soil Classification and American Association of State Highway and Transportation (AASHTO) classifications were made. The parameters which were determined as a physical properties are the Atterberg limits (liquid limit (LL) and plastic limit (PL)), maximum dry density ($\gamma_{dmax}$), optimum moisture content (OMC), cohesion (c), angle of internal friction (Ø) and the specific gravity ($G_s$). The chemical properties which were determined are; organic content, sulphate content ($SO_3$) and gypsum content.

*Table 1: Locations and Sides of Soil Samples.*

| Sample No. | Location | Side |
|---|---|---|
| 1 | Al-Nasr quarter | North-West |
| 2 | Al-Salam quarter | Middle |
| 3 | Al-Quds quarter | South-West |
| 4 | Al-Adala quarter | Middle |
| 5 | Al-Kufa | East |

**Tests**
*Sieve Analysis*
Sieve analysis is carried out for all samples and the grain size distribution according to ASTM (D 422-2007) is shown in Figure 1 [5].
*Atterberg Limits*
To classify the soil samples, it is necessary to calculate Atterberg limits. ASTM D 4318-standard test method for liquid limit (LL), plastic limit (PL), and plasticity index (PI) is adopted. The moisture content is calculated according to ASTM D 2216. Figure 2 shows the relationship between no. of blows and moisture content (m), from this figure it can be found that the liquid limit of each sample, which represents the moisture content corresponding to 25 no. of blows. Plastic limit (PL) and plasticity index (PI) for each sample are calculated also and used in the classification of soil samples later.
*Maximum Dry Density*
For all samples, maximum dry density and optimum moisture content are determined according to ASTM D 698 [6]. Figure 3 shows the relationship between the dry density and moisture content for each sample.
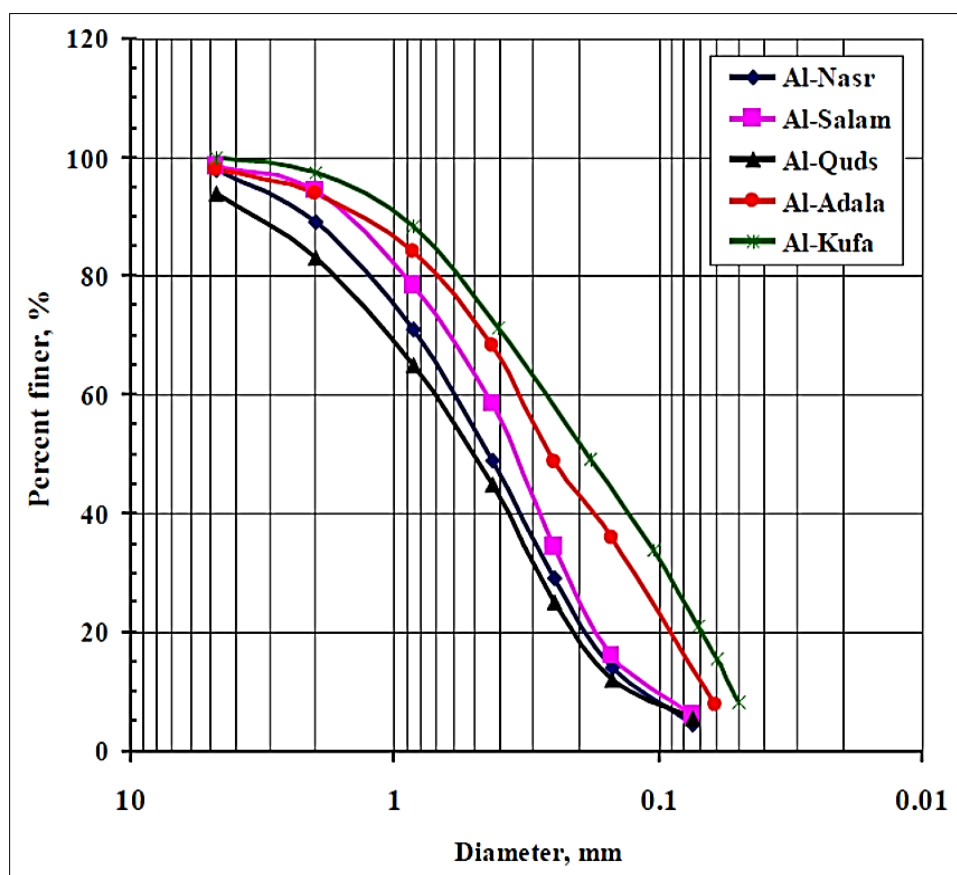
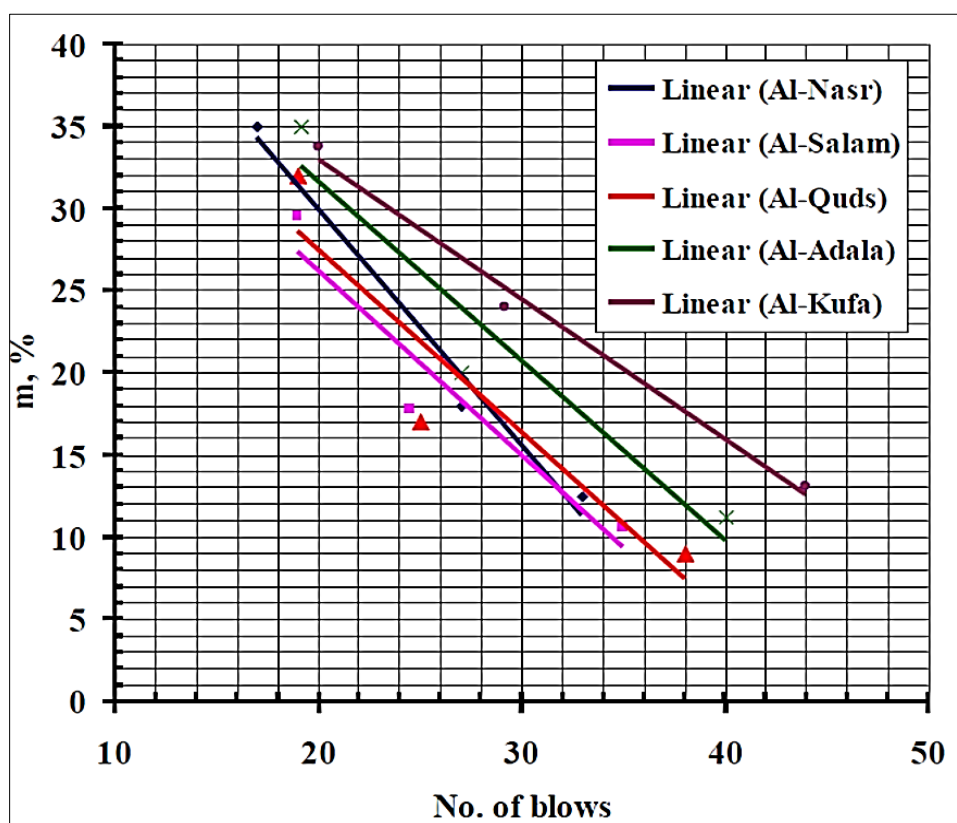***Fig. 1:** Grain Size Distribution of Samples.*



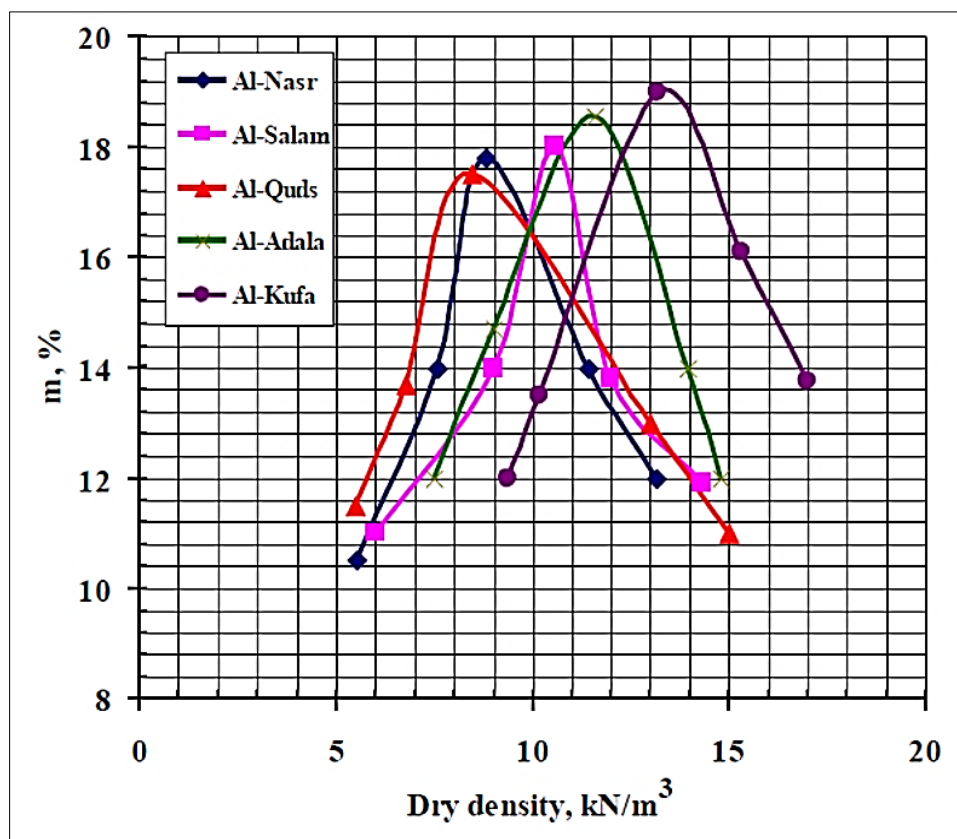***Fig. 2:** No. of Blows and Moisture Content Relationship.*

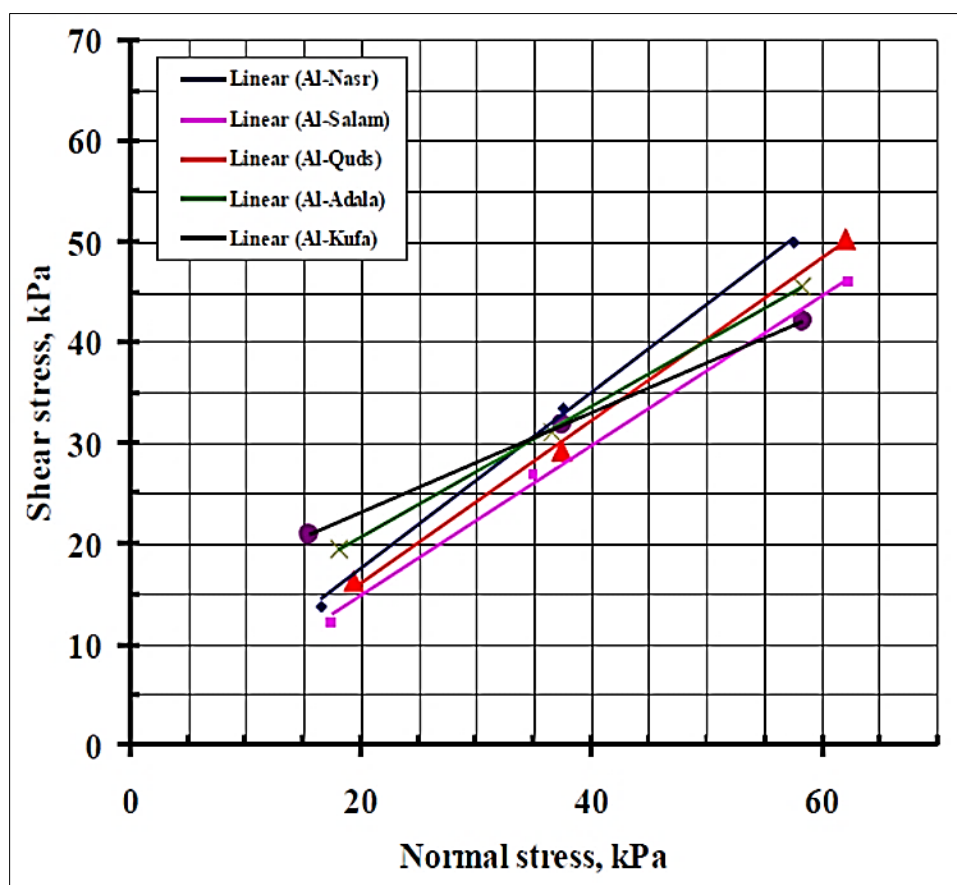***Fig. 3:*** *Relationship between Dry Density and Moisture Content for Proctor Test.*



***Fig. 4:*** *Relationship between Normal Stress and Normal Shear Stress (Direct Shear).*

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### Direct Shear

The direct shear test results are applicable in assessing strength in a field situation where complete consolidation has occurred under the existing normal stresses. Failure is reached slowly under drained conditions so that excess pore pressures are dissipated. The results from several tests may be used to express the relationship between consolidation stress and drained shear strength, (ASTM D 3080) [8]. The relationship between normal stress and shear stress at failure for the samples is drawn in Figure 4.

### Specific Gravity

The specific gravity of soil solids is used in calculating the phase relationships of soils, such as void ratio and degree of saturation. The specific gravity of soil solids is used to calculate the density of the soil solids. This is done by multiplying its specific gravity by the density of water (at proper temperature), ASTM D 854-02 [9]. The specific gravity ($G_s$) is calculated for the samples and listed in Table 2.

### Chemical Properties

The chemical properties which are investigated are; the organic content, sulphate content and gypsum content according to ASTM D-2974, BS 1377 and 1377 respectively [7, 10]. The results of chemical properties are listed in Table 3.

## RESULTS AND DISCUSSION

From the previous sections, the results of the tests can be analyzed to present a database for the locations, which cover a wide area of Al-Najaf city. The following part of the paper presents the analysis of the results.

### Soil Classification

As a result of rapid urban development in the province of Al-Najaf is necessary to classify the soil for the purpose of the establishment of buildings and projects such as hotels, factories and roads. The main two soil classification systems adopted in Iraq are the Unified Soil Classification and AASHTO. Figures 1 and 2 above show the grain size distribution and Atterberg limits of the samples; from these Figures, it can be found that the parameters which are used to classify the soil such as coefficient of uniformity (Cu), coefficient of curvature (Cc), percent finer of many sieves and Atterberg limits etc. Table 2 shows the soil samples type. The results present that the soil at the middle and west of city have a particles larger than the east soil, this because of the wide area of agricultural regions in Al-Kufa city near the river (Shatt Al-Kufa) east.

*Table 2: Physical Properties of Soil Samples.*

| Location | LL(%) | PL(%) | $\gamma_{dmax}$ (kN/m³) | OMC | c (kN/m²) | Ø° | $G_s$ | AASHTO | Unified |
|---|---|---|---|---|---|---|---|---|---|
| Al-Nasr quarter | 21 | 11 | 17.8 | 8.8 | 0 | 41.2 | 2.61 | A-1-b | SP |
| Al-Salam quarter | 22 | 11.5 | 18 | 10.6 | 0 | 36.5 | 2.62 | A-1-b | SP |
| Al-Quds quarter | 23 | 13 | 17.5 | 8.6 | 0 | 38.8 | 2.62 | A-1-b | SP |
| Al-Adala quarter | 26 | 14.5 | 18.5 | 11.6 | 7.6 | 33 | 2.63 | A-2-6 | SM |
| Al-Kufa | 29 | 15 | 19 | 13.2 | 13.2 | 26.3 | 2.64 | A-2-6 | SM |

*Table 3: Chemical Properties of Soil Samples.*

| Location | Organic content (%) | SO$_3$ (%) | Gypsum content (%) |
|---|---|---|---|
| Al-Nasr quarter | 1 | 2.6 | 27.8 |
| Al-Salam quarter | 1.5 | 2.3 | 18.7 |
| Al-Quds quarter | 1.3 | 2.5 | 28.3 |
| Al-Adala quarter | 1.8 | 2.2 | 15.1 |
| Al-Kufa | 2.9 | 2.7 | 13.6 |

**Physical Properties**

The physical properties which are discussed earlier in this paper are the maximum dry unit weight ($\gamma_{dmax}$), optimum moisture content (OMC), cohesion (c), angle of internal friction (Ø) and specific gravity (G$_s$). The values of Atterberg limits are listed in Table 1, it can be seen that the values of liquid limit (LL) at the middle and east of city is larger than the west which is supporting the grain size distribution curves.

**Chemical Properties**

The chemical properties of the soil samples are scheduled in Table 3. Chemical properties include the organic content, and sulphate content and gypsum content. The results show that the organic content is low in most localities area of city. The sulphate content (SO$_3$) varied from 2.2 to 2.7%, which is considered acceptable for construction purposes. The results show also that the assemblages of gypsum concentrated at the west part of city and decrease towards the east.

**CONCLUSIONS**

This paper presents an experimental study, which is concentrated on studying the engineering soil characteristics of Al-Najaf city in Iraq to give a data base which can be used for the future construction design. The work includes investigating the physical and chemical properties of five selected locations west, middle and east of the city where the localities are concentrated.

Many conclusions can be drawn from the results of the study as:

1. The common type of soil is poorly graded sand, it is classified as SP according to Unified Soil Classification and A-1-b according to AASHTO classification at the west and middle, the soil is classified as a silty sand SM and A-2-6 towards the east.
2. Liquid limit (LL) varies from 21 to 29% and plastic limit (PL) varies from 11 to 15%, the low value of LL and PL for the soil of western locations increasing towards the eastern locations.
3. Maximum dry density ($\gamma_{dmax}$) increase from west and middle of city towards the east. Minimum value of $\gamma_{dmax}$ is 17.5 kN/m$^3$ and maximum value is 19 kN/m$^3$ as well as for optimum moisture content which varies from 8.6 to 13.2%.
4. Cohesion of soil (c) varies from 0 to 13.6 kPa, the soil at the west and middle of the city have zero cohesion and the east locations vary from 7.6 to 13.2 kPa. The value of Ø decreases from the west towards the east and varies from 26.3 to 41.2 degrees.
5. The chemical properties results show that the organic content and sulphate content have a low value and can be acceptable according to Iraqi specification. The gypsum content varies from 13.6 to 28.3%. The assemblages of gypsum soil are concentrated in the west side of the city.

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